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Diversity, regeneration status and population structure of gum- and resin-bearing woody species in south Omo zone, southern Ethiopia

Muhamed Adem • Adefires Worku • Mulugeta Lemenih
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Abstract: South Omo Administrative Zone in Ethiopia is home to 18 indigenous ethnic groups whose livelihood is vulnerable due to recurrent drought and degradation. Despite the preliminary observation showing the rich dry-forest resource base that, if sustainably managed could enhance livelihoods and biodiversity conservation, there is lack of empirical data on its current status. We conducted a study aiming at quantifying the population status of gum- and resin-bearing species in two randomly selected districts, Hamer and Bena-Tsemay. Seventy-five quadrats (35 at Hamer and 40 at Bena-Tsemay) each measuring 400 m^2 were established along line transects to assess species diversity and equitability, density, frequency, dominance, importance value and population structure. We recorded a total of 27 woody species of 12 families and 14 genera. Fifteen species (9 at Hamer and 14 at Bena-Tsemay) of the genera *Acacia, Boswellia, Commiphora* and *Sterculia*, were identified as either major sources of commercial gums and resins or their adulterants. Gum- and resin-bearing species comprised 56% and 57% of species richness, 48% and 50% of total density per ha, 95% and 98% of basal area, and 64% and 56% of importance values at Hamer and Bena-Tsemay, respectively. Diversity of the entire woody species assemblage and of the gum- and resin-bearing species was slightly higher at Bena-Tsemay (H= 2.61, 1.4) than at Hamer (H′= 2.48, 1.28), respectively. The diversity and abundance of the resource base suggest potential for development of value-added commercialization of gum and resins to enhance livelihoods and encourage sustainable management of the forest at these study areas. We recorded, however, declining natural regeneration of most gum- and resin-bearing species, and this calls for integrated and participatory species management and landscape rehabilitation.

Keywords: *Acacia*, *Boswellia*, *Commiphora*, *Sterculia*, gum and resins, population status, southern Ethiopia

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Introduction

Ethiopia is an ancient country whose ecosystems have been exposed to numerous anthropogenic impacts that have resulted in heterogeneous vegetation formations (Demissew et al. 2005). WBISPP (2005) listed nine distinct vegetation types with widely varying species composition and agro-ecological distribution. Recent professional discussions in Ethiopia (e.g. Lemenih and Woldemariam 2008) recognized high forests, woodlands and bamboo thickets as forests. Lemenih and Kassa (2011) reported that the vast woodlands of Ethiopia, also known as dryforests, account for the largest proportion of forest and are among the predominant landscape features of the dryland and lowland regions of the country. Dry forests are known to support high species diversity and endemism. Perhaps one in four species in Ethiopian is found only in dry lands in the species-rich south and southeast forests that are characterized by two of the most prominent genera: *Acacia* and *Commiphora* (Woldu 1999; WBISPP 2005; Lemenih and Kassa 2011; Worku et al. 2011a). The other peculiar woodland formation with diverse species composition is the *Combretum-Terminalia*, broadleaved deciduous vegetation type that occurs mainly in the northern and northwestern low-lying periphery of the country (Gebrehiwot 2003; WBISPP 2005; Eshete et al. 2011).

In addition to the rich diversity and endemism of dry forests, they also support livelihoods via provisioning of socio-economically essential forest products, both timber and non-timber (Lemenih et al. 2003; Ogbazghi et al. 2006; Lemenih et al. 2007; Worku et al. 2011b). The known major forest products that originate from dry forests are gums and resins, medicines, fodder, fuel wood, and foods (FAO 2010; Worku et al. 2011b; Lemenih and Kassa 2011). According to Worku et al. (2014) for instance, in the Liben and Afdher zones of Somali region, in addition to using dry forests as a main source of rangelands, local communities collect and sell various forest products that account for up to 38% and 46% of their annual cash income respectively. Both large areas in the drylands of Ethiopia and the livelihoods of the pastoral and agro-pastoral communities living in the dry land ecosystems are fragile. According to Lemenih and Teketay (2004) and Kassahun et al. (2008), recent observations showed clear sign of vulnerability to desertification of such fragile ecosystems in various areas in Ethiopia. Sustainable management of dry forests is therefore crucial to livelihood enhancement, combating desertification, and conservation of biodiversity Teketay (2004-5).

Despite the ecological and socio-economic significance of dry forests, few policies and practices try to address issues related to these versatile resources when planning development of drylands in Ethiopia (e.g. Lemenih et al. 2003; Lemenih et al. 2007; Worku et al. 2011a). Lack of up-to-date information on the population status of high value tree species, especially those that produce commercial gum and resins at national scale is among the key factors hindering strategic consideration of dry forests (Eshete et al. 2011). Although they are highly important in Ethiopia, dry forests, mainly those in the south and south west are studied less intensively compared to moist forests (Teketay 2004-5). Studies on dry forests to date have concentrated at the northern parts of the country in forests dominated by Boswellia population (Gebrehiwot 2003; Eshete et al. 2011). The shortage of knowledge from other localities has not only hindered strategic integration of the resource base, but has also encouraged continued conversion of dry forests to other land uses (Teketay 2004-5; Lemenih and Woldemariam 2010; Lemenih and Kassa 2011; Woldeamanuel 2011; Worku et al. 2011a, b).

In the Southern Nations, Nationalities and Peoples Regional State in Ethiopia, frequent and extended severe drought is jeopardizing the livelihoods of the traditional pastoral and agro-pastoral communities (Ethiopian NAPA 2007). With increasingly unpredictable climatic conditions, future development approaches should be more resilient and benefit the mass population. Maintaining dry forests on the landscape and developing markets for forest products could help to simultaneously address livelihood and environmental issues (Arnold and Perez 2001; Lemenih and Teketay 2004; Yemi et al. 2009; Worku et al. 2011b). This however, demands knowledge of the current population status of the dry forests. Case studies to date in various localities in Ethiopia identified 12 *Acacia*, 17 *Commiphora,* six *Boswellia* and three *Sterculia* species as potential yielders of commercial gums and resins from dry forests (Lemenih et al. 2003; Worku et al. 2011a, b). Preliminary reports also suggest

the presence of extensive gum- and resin-bearing dry forest in the south Omo zone. But there has been no empirical research on the population status of the gum- and resin-bearing species to identify possibilities for promoting value-added gum and resin marketing and sustainable management of these versatile species. The aim of this study was, therefore, to quantify the diversity, abundance, distribution, regeneration status, and population structure of gum- and resin-bearing species in the south Omo zone of southern Ethiopia and to outline options for their management.

Materials and methods

Study areas

This study was conducted in South Omo zone, one of the 13 zones of the Southern Nations, Nationalities and People's Regional State in Ethiopia (Fig. 1). We selected this zone based on preliminary information indicating the presence of extensive dry forest predominated by diverse and abundant gum- and resin-bearing species (e.g. EPA 1998; Admasu et al. 2010). It was also thought that most south Omo zone pastoral and agro-pastoral communities rely heavily on dry forest resources for livestock fodder, income, food and medicine. As local livelihoods depend on key resources including land, water, forests, livestock and pasture, the environment poses particular challenges to human survival. Hence, a study that contributes to the strategic management of natural resources such as dry forest is crucial.

South Omo zone lies between the lower reaches of the Omo River in the west and the Woito and Sagan rivers in the east. With a population of 577,673 (CSA 2007), the zone is unique in that it comprises 18 of the 80 distinct ethnic groups in the country and is known as the heart of cultural diversity. Districts in the zone support diverse dry forests where gum- and resin-bearing species account for most of the vegetation formation (EPA 1998; Admasu et al. 2010). Field reconnaissance surveys and discussions with key informants were carried out to obtain an overall picture of the zone. Two districts, Hamer and Bena-Tsemay were randomly selected using the list of the gum and resin potential districts within the zone. Previous studies (e.g. Lemenih et al. 2003; Worku et al. 2012) selected study sites following more or less similar procedures.

Hamer district is located at 4°30′–5°28′ North and 36°9′–36°54′ East, some 739 km from Addis Ababa. The district borders Kenya to the south. Elevations range from 271 to 2,022 m.a.s.l. Bena-Tsemay is located at 5°1′–5°44′ North and 36°23′–37°4′ East, about 839 km from Addis Ababa. Elevations range from 567–1,800 m.a.s.l (Admasu et al. 2010). Agro-ecologically, both districts were categorized as dry tropical to tropical desert climate whose annual precipitation does not exceed 250 mm. Rainfall is bimodal in both districts, with long rains during April-June and short rains during September-October. Admasu et al. (2010) noted that rainfall has become more erratic during the last two decades. Local communities

complain of increasingly intense solar radiation, which reduces livestock and plant productivity. Average annual minimum and maximum temperatures range from 32–38°C at Hamer and 16–40°C at Bena-Tsemay (Admasu et al. 2010). Drought has become severe in the area and has reportedly limited coping options (Seyoum 2010). Socio-economically, both districts are known to support some of the poorest people living on traditional pastoralism, but also with evolving traditions of crop production, mainly along the river banks. Although at a subsistence level, dependence on environmental income was very high (Seyoum 2010).

The vegetations of the study districts can be broadly classified as desert and semi-desert scrub, *Acacia-Commiphora* woodland and *Combretum-Terminalia* woodland. It is a mixture of *Acacia, Boswellia, Commiphora, Balanites* and various other woody species and short grasses at varying densities (Soromessa et al. 2004; Admasu et al. 2010). The dryforests in both districts support diverse and abundant wildlife. Murule, one of the 17 controlled hunting areas in Ethiopia is located in Hamer district. According to the elderly people, 40 years ago, land was almost all owned communally. Currently however, pastoralists own small plots of rangeland within enclosures near their croplands and around their homesteads. The rest of the vast rangeland is still owned communally, and ownership of the rangeland is similar to that in many pastoral areas in Ethiopia (Kassahun et al. 2008; Dalle et al. 2005).
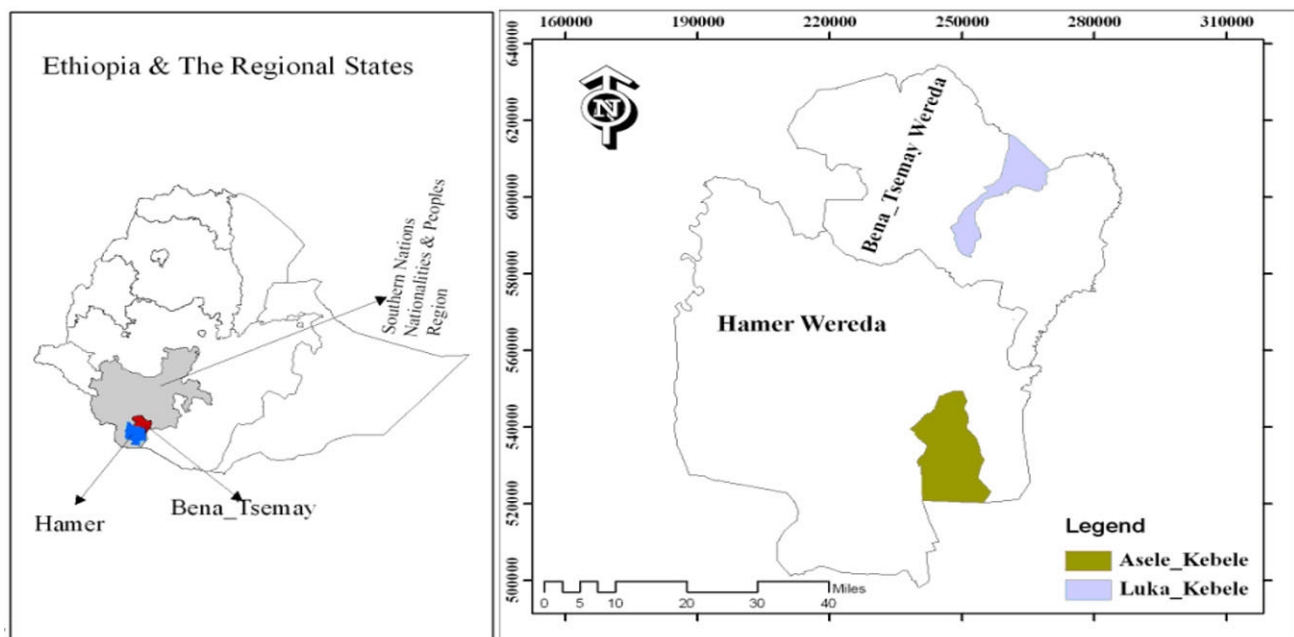

Fig. 1: Map of Ethiopia showing location of the study areas.

Data collection

At Hamer, 35 quadrats, each measuring 20 m × 20 m (400 m^2) were established along seven transect lines separated by 500 m. The interval between quadrats was also 500 m. Similarly, at Bena-Tsemay, 40 sample quadrats were established along eight transect lines following Kent and Coker (1992) and Pearson et al. (2005). We collected data from the first sample quadrats on line transect and then progressing to the next quadrat in an east-west compass direction. In each quadrat, we recorded data on species identity, abundance, frequency and regeneration for all woody species rooted in the sample plots. Diameter at breast height (DBH) was measured for individuals ≥1.5 m in height using diameter tape. Seedlings (<1.5 m height) were counted and recorded. Most plant species were identified in the field but voucher specimens were prepared unknown species, which were identified at the National Herbarium of Addis Ababa University (Edwards et al. 2000; Hedberg et al. 2006).

Data analysis

We analyzed data to compute ecological variables according to Magurran (1988). These included: (1) density (DE) of woody species was computed by converting the total number of individual of each species to equivalent numbers per hectare; (2) relative density (RDE), which is the number of individuals of a species divided by the total number of individuals of all species; (3) frequency (FR) was the number of sample plots in which the species was encountered, where (4) relative frequency (RFR) was computed as the ratio of the number of plots in which a species occurred and the total occurrences of all species in all plots; (5) dominance (DO) was calculated as the sum of the basal areas (BA) of the individual woody species in m^2 per ha. BA was calculated for all woody species as BA = Πd2/4, where BA = Basal area in m^2, d = Diameter at breast height in cm, Π =3.14; (6) relative dominance (RDO) is the ratio of the basal area of a spe-

cies divided by the sum of basal areas of all species; (7) importance value index (IVI) was the summation of RDE + RFR + RDO and presented in percentage (Curtis and McIntosh 1950; Lamprecht 1989; Kent and Coker 1992; Akwee et al. 2010). Finally, (8) heterogeneity of the entire species assemblage and that of gum- and resin-bearing species only was determined using Shannon-Weiner diversity and Evenness indices. Sorenson's similarity coefficient was used to quantify similarity (Krebs 1989). Analyses were made using Biodiversity Professional version 2 software (Neil 1997). In addition, population structure of the entire vegetation and gum- and resin-bearing species alone was investigated via constructing diameter frequency histograms, where the density of all individuals including seedlings (if any) were presented on the Y-axis and diameter classes on the X-axis (Eshete et al. 2011).

Results

Floristic composition

In total, 27 woody species were recorded, 16 at Hamer representing 7 families and 26 at Bena-Tsemay representing 12 families (Table 1). Fifteen species occurred in both districts. Burseraceae was the most diverse family with four species (31%) at Hamer and 10 species (38%) at Bena-Tsemay. Fabaceae and Tiliaceae ranked second and third in terms of diversity at both study districts. Family Salvadoraceae and Capparadaceae were represented by two species each, and four families were each represented by just one species (Table 1).

Table 1: Species recorded in sample quadrats at Hamer and Bena-Tsemay Districts

Species scientific name	Family	Plant form	Hamer				Bena-Tsemay			
			RDE	RFR	RDO	IVI	RDE	RFR	RDO	IVI
*Acacia mellifera (*Vahl) Benth.	Fabaceae	* Tree/shrub	5.54	5.08	3.8	14.42	0.82	0.03	1.26	2.11
Acacia nilotica (L.) Willd.ex Del.	Fabaceae	Tree	2.77	1.6	0.46	4.83	4.32	0.07	4.21	8.6
Acacia nubica Benth.	Fabaceae	* Tree/shrub	0.83	1.6	0.5	2.93	-	-	-	-
Acacia senegal (L.) Willd.	Fabaceae	* Tree/shrub	2.02	4.28	0.42	6.72	8.08	4.99	6.74	19.81
Acacia tortilis (Forssk.) Hay.	Fabaceae	*Tree	-	-	-	-	0.87	0.6	1.32	2.79
Albizia schimperiana Oliv.	Fabaceae	Tree	-	-	-	-	0.27	0.03	0.6	0.9
Balanites aegyptica (L.) Del.	Balanitaceae	Tree/shrub	1.38	2.69	0.76	4.83	0.41	0.8	1.27	2.48
Boscia mossambicensis Klotzsch	Capparidaceae	Tree	14.20	9.09	0.84	24.13	14.9	0.92	7.37	23.19
Boswellia neglecta S. Moore	Burseraceae	* Tree/shrub	11.1	9.36	55.21	75.67	14.4	57	8	79.4
Combretum aculeatum Vent.	Combretaceae	Tree	-	-	-	-	0.18	0.03	0.48	0.69
Commiphora africana (A. Rich.) Engl	Burseraceae	* Tree/shrub	4.6	8.29	10.11	23	8.64	10.7	7.37	26.71
Commiphora boiviniana Engl.	Burseraceae	Tree/shrub	-	-	-	-	0.78	0.92	1.47	3.17
Commiphora boranensis Vollesen	Burseraceae	* Tree/shrub	-	-	-	-	4.59	8.2	6.3	19.09
Commiphora bruceae Chiov	Burseraceae	* Tree/shrub	-	-	-	-	0.8	0.71	1.05	2.56
Commiphora cyclophylla Chiov	Burseraceae	* Tree/Shrub	-	-	-	-	0.27	0.03	1.05	1.35
Commiphora myrrh (Nees) Engl	Burseraceae	*Tree	1.38	3.74	0.8	5.92	0.91	0.63	6.95	8.49
Commiphora schimperi (O.Berg) Engl	Burseraceae	* Tree/shrub	9.98	8.56	13.44	31.98	2.52	4.31	6.1	12.93
Commiphora terebinthina Vollesen	Burseraceae	* Tree/shrub	9.75	8.29	10.13	28.17	2.98	5.1	4.63	12.71
Dobera glabra	Salvadoraceae	Tree/shrub	-	-	-	-	0.37	0.03	1.05	1.45
Euphorbia tirucalli L.	Euphorbiaceae	Shdrub	-	-	-	-	0.5	0.03	1.47	2
Grewia bicolar Juss.	Tiliaceae	Shdrub	13.9	9.09	1.23	24.22	10	0.22	7.16	17.38
Grewia tenax (Forssk.) Fiori	*Tiliaceae*	Shdrub	9.7	9.09	0.23	19.02	8.64	0.35	6.31	15.3
Grewia villosa Willd	Tiliaceae	Shdrub	6.92	9.09	0.5	16.51	9.01	0.7	6.74	16.45
Maruwa angolenesis DC	Capparaceae	Tree/shrub	0.33	1.06	0.3	1.69	0.46	0.07	1.26	1.79
Salvadora perisca L.	Salvadoraceae	Tree/shrub	-	-	-	-	0.37	0.03	1.84	2.24
Sterculia africana (Lour.) Fioris	Sterculiaceae	*Tree	-	-	-	-	0.5	2.6	1.26	4.36
*Tarenna graveolens (*S.Moor)Bremek	Rubiaceae	Tree/shrub	5.6	9.09	1.27	15.96	4.41	0.9	6.74	12.05
Total			100	100	100	300	100	100	100	300

Total density per ha = 1804 and 2162 at Hamer and Bena-Tsemay, respectively. [RDE (%) = relative density, RFR (%) = relative frequency, RDO (%) = relative dominance, IVI = Importance Value Index (%). *Gum- and resin-producing species, as identified by local communities. Most of these species are also mentioned in similar studies in other parts of the country (E.g. Lemenih et al. 2003; Worku et al. 2011a).

Gum- and resin-bearing species were more numerous than others, especially those of the genus *Commiphora*. A total of 15 woody species (nine at Hamer and 14 at Bena–Tsemay) were identified as sources of either commercial gum and resins or adulterants. *Commiphora* and *Acacia* were most diverse at both sites and were represented by nine species and five species, respectively. *Sterculia* and *Boswellia* were each represented by one

species. Tree was the dominant life form with 12 species (43%), while tree-shrub was represented by 11 species (40.5%), and shrub was represented by four species (16.7%).

Four species from the genus *Commiphora* (*C. boiviniana, C. cyclophylla, C. bruceae, C. boranensis* and *Sterculia africana*) that were recorded at Bena-Tsemay were not recorded at Hamer district. Excluding *Acacia nubica*, all other associated woody

species encountered at Hamer were also recorded at Bena-Tsemay district. In total, gum- and resin-bearing species comprised 56% and 54% of the species composition at Hamer and Bena-Tsemay, respectively.

Density, frequency and dominance

The total density of all woody and gum- and resin-bearing species was 1804 and 919 ha^{-1} and 2162 and 1085 ha^{-1} at Hamer and Bena-Tsemay, respectively. *Boscia mossambicensis, Grewia bicolar, G. tenax, C. schimperi, C. terebinthina* and *B. neglecta* were the most densely populated species, constituting 68.5% of overall density at Hamer. *B. mossambicensis, G. villosa, B. neglecta, G. tenax, A. senegal* and *C. africana* were the dominant species, accounting for 74% of recorded species density at Bena-Tsemay. The lower diameter class was dominated by *Grewia* species and *B. mossambicensis* at both districts.

Gum- and resin-bearing species comprised 48% and 50% of overall density ha^{-1} at Hamer and Bena-Tsemay, respectively (Fig. 2). At Hamer, *B. neglecta, C. schimperi,* and *C. terebinthina* were the most abundant species, each represented by 200, 180 and 176

individuals per ha. The second-most abundant species were *A. mellifera and C. Africana*, with 100 and 84 individuals per ha. At Bena-Tsemay, *B. neglecta, A. senegal* and *C. africana* were dominant, each represented by 313, 188, and 175 stems per ha. *C. boranensis, A. nilotica, C. schimperi* and *C. terebinthina* ranked second in density, each represented by 94, 94, 64 and 55 stems per ha. The total basal area for all woody species was 26.6 m^2 per ha at Hamer and 28.02 m^2 per ha at Bena-Tsemay. The basal areas of gum- and resin-bearing species were 25.52 (95%) and 27.02 (96%) m^2 per ha at Hamer and Benna-Tsemay, respectively.

At Hamer, the least and greatest frequencies were four and 35, with four and 38 at Bena-Tsemay. The most frequent gum- and resin-bearing species at Hamer was *B. neglecta*. It was encountered in 35 quadrats, whereas, C. *schimperi, C. africana* and C. *terebinthina* were recorded in 32, 31 and 31 of 36 sampled quadrats. At Bena-Tsemay, *B. neglecta* was most frequent and recorded in 38 of 40 sample quadrats, followed by *C. africana, C. myrrh, A. senegal* and *C. boranensis,* each recorded in 35, 33, 32 and 30 quadrats, respectively. *Bosica mossambicensis, G. villosa, G. tenax, G. bicolar* and *T. graveolens* were the most frequent associate species in both districts.
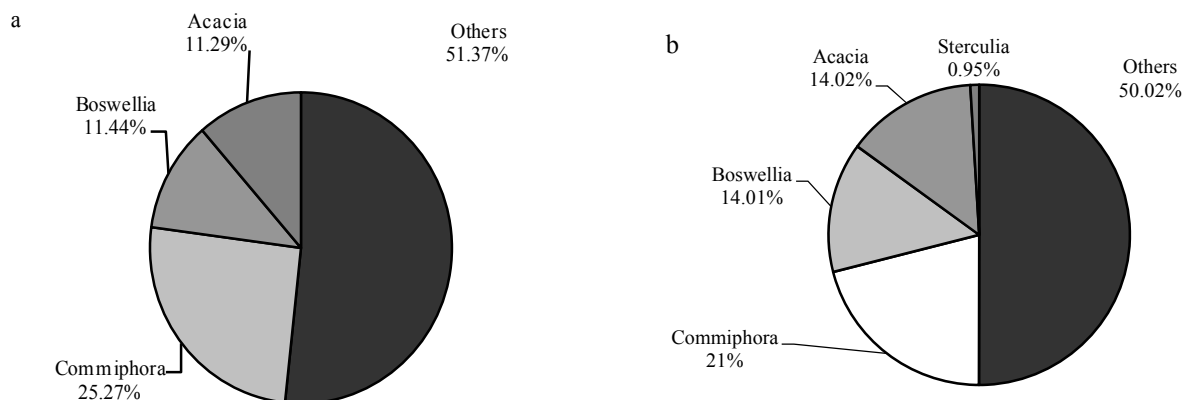

Fig. 2: Proportion of the density (stem number) per ha of gum- and resin-bearing and associated species at Hamer (a) and Bena-Tsemay (b) Districts, respectively, South Omo Zone, Southern Ethiopia.

Importance value index (IVI)

Gum- and resin-bearing species demonstrated high IVIs of 63.63% and 55.79% at Hamer and Bena-Tsemay, respectively. *Boswellia neglecta, C. schimperi, C. terebinthina* and *C. africana* were species with highest IVI and constituted about 52.5% of total IVI at Hamer. Other important species included *A. mellifera* and *C. africana. Boswellia neglecta, C. africana, A. senegal* and *C. boranensis* at Bena-Tsemay contributed 50% of total IVI (Table 1). At Hamer, *Maruwa angolenesis* and *A. nubica* and at Bena-Tsemay, *Albizia schimperi, Combretum aculeatum, Maruwa angolenesis, Dobera glabra* and *Commiphora cyclophylla* had the lowest IVIs.

Diversity, evenness and similarity

The Shannon-Wiener diversity indices (H′) for all woody species

and gum- and resin-bearing species were (H′ =2.48 and 1.28) at Hamer and (H′ =2.61 and 1.4) at Bena-Tsemay, respectively. Shannon evenness indices (J') for all woody species and gum- and resin-bearing species were (J =0.76, 0.42 and 0.64, 0.35, respectively) at Hamer and Bena-Tsemay. Sorensen's Similarity coefficient for all species at the two sites was 42% and was 44% for gum- and resin-bearing species.

Regeneration and population structure

Except for a few species, for example *C. shimperi* and *A. senegal* at Hamer and Bena-Tsemey districts, either none or very few seedlings were recorded for most tree and shrub species in general and for gum- and resin-bearing species in particular. Analysis of diameter size class distribution of all species showed similar patterns in both districts (Fig. 3). Unlike, most gum- and resin-bearing species, the first four diameter classes of the entire

vegetation were represented by relatively high numbers of stems and densities declined sharply at higher diameter classes. The first and second diameter classes were dominated by *G. villosa, G.* *bicolar* and *G. tenax*, and the third and fourth by gum- and resin-bearing species.

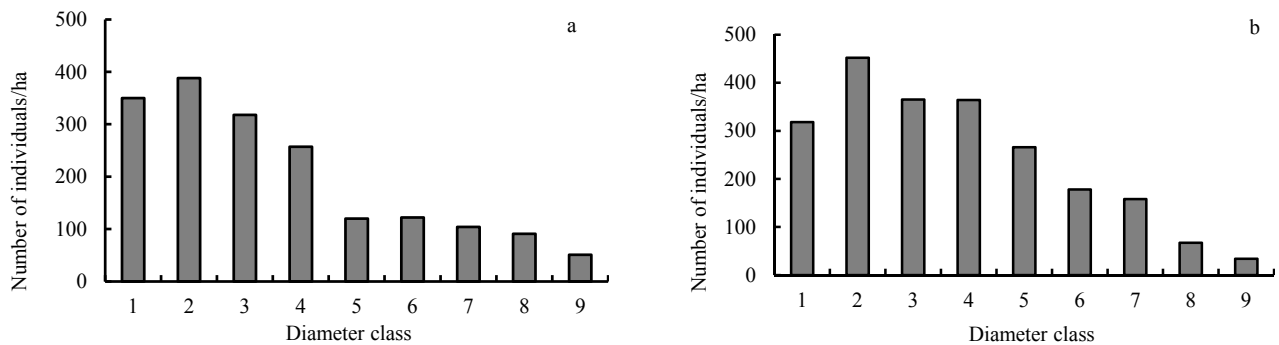**Fig. 3:** Diameter class distribution of the entire vegetation at Hamer (a) and Bena-Tsemay (b). Diameter size class in (cm) (1: < 5, 2: 5−10, 3: 10−15, 4: 15−20, 5: 20−25, 6: 25−30, 7: 30−38, 8: 38−47, 9: > 48).

The population structure of gum- and resin-bearing species can be categorized more or less into two groups: J-shape and bell-shape diameter distribution patterns. *Boswellia neglecta* in Hamer and *S. setigera* in Bena-Tsemay districts exhibited J-shape, which was an unhealthy distribution due to the lack of seedlings (Fig. 4 & 5). *Boswellia neglecta* in particular had no individuals in the first diameter class. The rest major gum and resin bearing species in both districts more or less demonstrated a bell-shape distribution, where there was small number of indi-viduals in the lower and higher diameter classes. Although they all had bell-shape distribution, *C. terebinthina* and *C. schimperi* in Hamer and *A. senegal* and *C. schimperi* in Bena-Tsemay got some individuals of seedlings and/or sapling that belong to the first class, compared to *C. myrrha, C. africana* and *A. sengal* in Hamer and *B. neglecta, C. boranesis* and *C. myrrha* in Bena-Tsemay, which demonstrated hampered regeneration (Fig. 4 & 5).
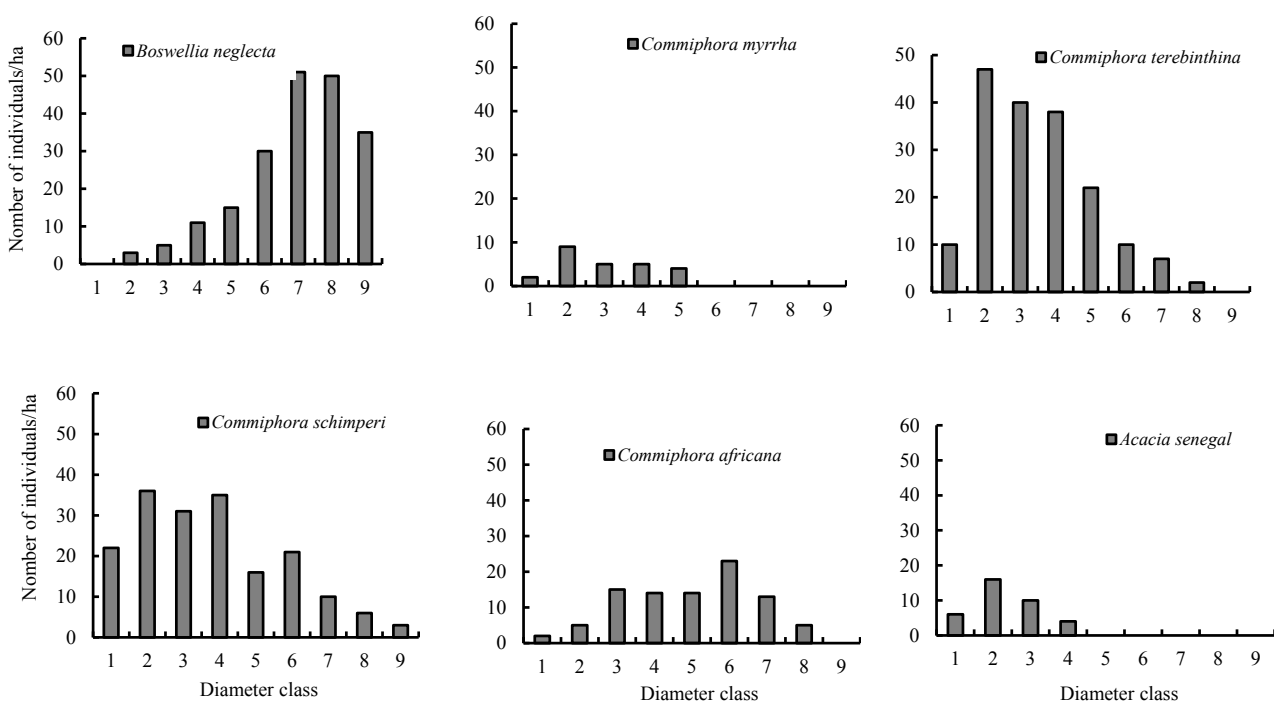

Fig. 4: Diameter class distribution of selected gum- and resin-bearing species at Hamer. Diameter class in (cm) 1: < 5, 2: 5−10, 3: 10−15, 4: 15−20, 5: 20−25, 6: 25−30, 7: 30−38, 8: 38−47, 9: > 48).

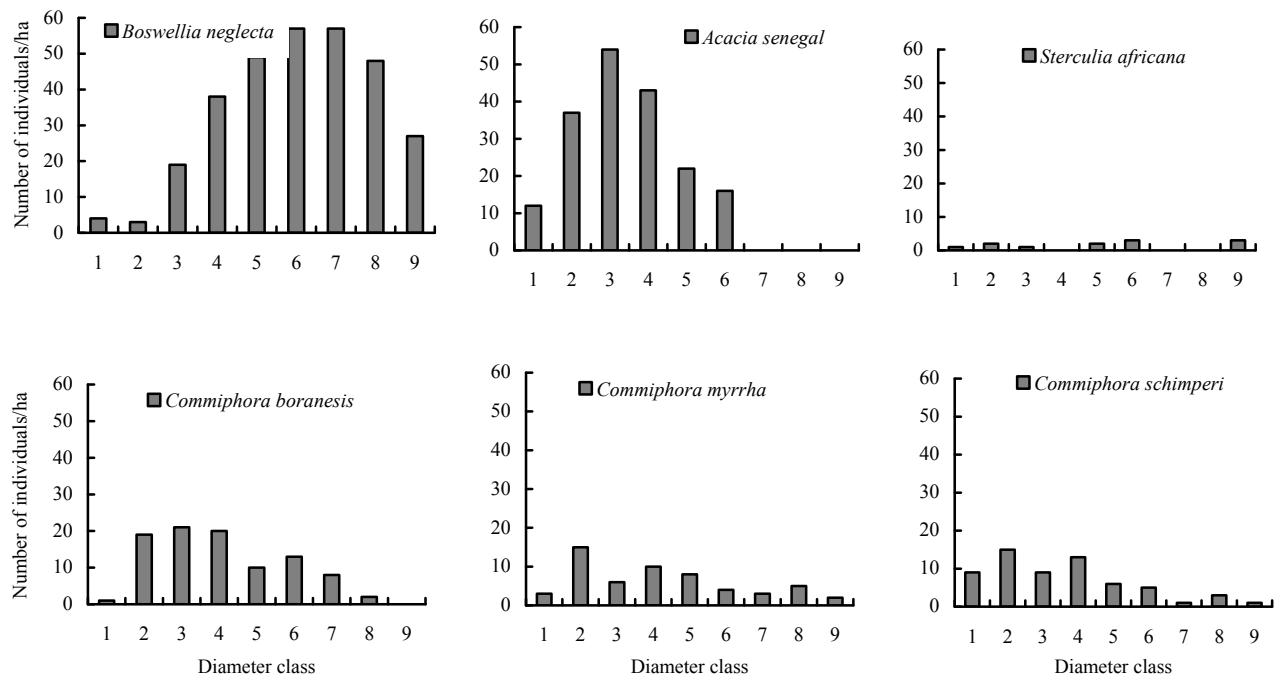**Fig. 5:** Diameter class distributions of gum- and resin-bearing species at Bena-Tsemay. Diameter class in (cm) 1: < 5, 2: 5–10, 3: 10–15, 4: 15–20, 5: 20–25, 6: 25–30, 7: 30–38, 8: 38–47, 9: >48 cm.

Discussion and recommendations

The south Omo zone supported high diversity of gum- and resin-bearing species compared to other areas in Ethiopia with similar agro-ecology. Argaw et al (1999), for example, reported only two gum- and resin-bearing species (*A. senegal* and *A. seyal*) from the central Rift valley woodlands. Although equivalent in terms of total species diversity, fewer gum- and resin-bearing species were reported from northern Ethiopia compared to the current study area (e.g. Eshete et al. 2011). In this part of the country, *B. papyrifera, A. senegal, A. seyal* and *S. setigera* were the main sources of commercial gum and resins (Gebrehiwot 2003; Eshete et al. 2011). However, the gum- and resin-bearing species diversity from South Omo proved comparable with findings in Borana zone, South Ethiopia (Worku et al. 2011a). Lemenih et al. (2003) recorded eight gum- and resin-bearing species in Liben zone, Somali Region, southeastern Ethiopia. These findings suggest that the southern and southeastern part of the country support more diverse gum- and resin-bearing species, and hence greater opportunity for marketing of different products (Lemenih and Kassa 2011; Worku et al. 2011a, b).

Densities and basal areas for gum- and resin-bearing species can be taken as indices of the probable amount of gum and resins to be collected from a particular species and area: the higher the density, the more product can be collected (Lemenih et al. 2003). In South Omo zone, gum- and resin-bearing species occurred at

high density ha^{-1} (48% and 50% of all species density), comparable to levels reported from other gum and resin production localities in Ethiopia. For instance, Worku et al. (2012) reported total density per ha of 1017 and 882 (49% and 68% of the total woody stems density) at Arero and Yabello districts in Borana zone, Oromia region in Ethiopia. However, density typically varies greatly by species. For instance, it ranged from 11 to 313 at South Omo and 12 to 162 at Borana. Eshete et al. (2005) reported stem densities per ha from 87 to 175 for *B. papyrifera* at Amhara region, northern Ethiopia, while Gebrehiwot (2003) counted between 100 and 254 stems per ha for similar species in Tigray Region, northern Ethiopia. Such great variation in stem densities might be due to the effect of land use history, climate regime and species characteristics. In general, the stem density at South Omo zone suggested potential for commercial gum and resin tapping in this area.

Similar to density, dominance also reflects the ground cover of a plant species rather than simple number (Lamprecht 1989) and can be important indicator of possible mass production of gum and resins. The average basal area of gum- and resin-bearing species was 26.3 m^2 per ha at South Omo, quite a high figure compared, for instance, to the average of 7 m^2 per ha at Borana zone (Worku et al. 2012). There was a difference in the horizontal distribution of some of the gum- and resin-bearing species. For instance, *C. boranensis, C. erytherna, C. boiviniana, C. cyclophylla, S. africana* and *C. bruceae* were all frequent at Bena-Tsemay but were not recorded at Hamer. Species such as *B. neglecta, C. schimperi, C. terebinthina, C. africana* and *C. myrrh*

were generally frequent at both districts. The limited local distribution for some of the gum- and resin-bearing species might be due to their habitat preferences. For instance, *B. neglecta* and most of the *Commiphora* species were highly concentrated on rocky and sloping sites, but were scarce on the flatlands and on sandy soil. Similar distribution was reported for *B. papyrifera* (Eshete et al. 2011).

Importance value index (IVI) is a useful parameter for comparison of the ecological significance of a species, since it reflects the combined effect of species density, frequency and dominance (Kent and Coker 1992; Akwee et al. 2010). It enables prioritizing species for management and conservation interventions: species with lowest IVIs might benefit from conservation and management interventions (Lamprecht 1989). Gum- and resin-bearing species were the pre-dominant components of the studied vegetations, as demonstrated by high IVI values (63.63% at Hamer and 55.79% at Bena-Tsemay). This implies their ecological significance to the ecosystem (Akwee et al. 2010). Greater diversity was recorded at Bena-Tsemay than at Hamer for all woody species and also for gum- and resin-bearing species. The observed variation in species richness and evenness between the two study sites could be due to habitat heterogeneity, site productivity, and/or disturbance regimes (Magurran 1988).

Information on population structure of a tree species indicates the history of the past disturbance to that species and the environment and hence, and can be used to forecast the current and future perpetuation of the population (Peters 1996). Ecologists often use population structure as an indicator of the overall species regeneration profile and to recommend suitable development interventions (Tripathi et al. 2010; Eshete et al. 2011). According to these authors, a species population with inverted J-shape population structure could be considered healthy and hence more amenable to sustainable management. In contrast, the population structure of the entire vegetation at the current study sites showed more stems per ha at lower diameter classes, implying a more stable population (Krebs 1989). Nevertheless, as indicated in Figs. 4 and 5, the population structures of most of the high value gum- and resin-bearing species depicted unhealthy populations. *Boswellia neglecta* and *C. africana* at Hamer and *Sterculia africana* in particular were typical of this type, where they showed critically hampered regeneration. Such a J-shape population structure was also reported for *B. papyrifera* in northern Ethiopia (Gebrehiwot 2003; Eshete et al. 2005; Eshete et al. 2011) and in Eritrea (Ogobaghi et al. 2006). Worku et al. (2012) reported that few gum- and resin-bearing species showed critically hampered regeneration in Borana, Oromia region, where there is similar land use and agro-ecology.

Eshete et al. (2005) and Worku et al. (2012) argued that sustainable supply of gum and resins from dryforests could be achieved given the current population structure of the entire forest and/or particular species. To achieve stable levels of trade volume in gum and resin, a species needs many seedlings and saplings in comparison to the stem counts for higher diameter classes to ensure species perpetuation. Simultaneously, the forest must support many trees in the middle and higher diameter classes because these trees are the ones that are tapped

right-away to produce commercial products (Lemenih et al. 2003; Yebeyen 2006; Worku et al. 2012). Local communities mentioned heavy grazing and frequent drought as major factors limiting regeneration of most woody species. In general, the population structures of most gum- and resin-bearing species in South Omo suggested that development and conservation interventions could facilitate natural regeneration while nursery propagation and participatory reforestation and afforestation schemes would also be needed.

Numerous seedlings were counted for *Acacia* species, possibly due to their lower palatability: grazers dominated the livestock composition at South Omo in contrast to the high numbers of browsers in other parts of Ethiopia's pastoral region, such as the Somali region (Kassahun et al. 2008). Gum bearing *Acacia* species showed inverted J-shape diameter distributions in Boaran zone (Worku et al. 2012). The dense seedlings of *C. schimperi* could be due to the fact that seedlings of this species grow well under the thorny *Acacia* canopy, which might provide protection from grazing/browsing. In general, the observed declining regeneration profile of gum and resin species on our study areas was similar to the situations reported for the various gum and resin belts in the country (Argaw et al. 1999; Yebeyen 2006; Eshete et al. 2011; Worku et al. 2012). It is important to note that we sampled only during the dry season and regeneration might differ during wet seasons, a subject for further study.

In conclusion, except for the poor regeneration profiles of some gum- and resin-bearing species that need management interventions, the species diversity, abundance and distribution of these species suggest potential to develop value-added marketing of gum and resins. This could increase incomes of climate-vulnerable pastoral and agro-pastoral communities, thereby encouraging their participation in sustainable management of the degrading dry forest resources. We offer the following recommendations to achieve this goal:

1. To improve the current poor natural regeneration, we need to establish community-based and state-promoted nurseries and rehabilitation projects where gum- and resin-bearing species will be propagated, planted and managed via participatory afforestation and reforestation schemes.

2. To our knowledge, this study was the first to carry out formal survey to assess the gum- and resin-bearing resources base of the South Omo area. Further research is needed to cover the wet season and other sites, and to provide analysis of factors contributing to poor regeneration and to identify practicable dry-forest sustainable management options.

3. Mobilizing local poor communities to sustainably manage their forest will require improving livelihoods. Enabling dryforests management and product development and marketing could be one way to enhance local participation. However, to secure the socio-economic contribution of the gum- and resin-bearing resources, it is necessary to raise the low level of awareness among herders, local experts and administration. Priority subjects are the national and international demand for gum and resin products, their importance as sources of increased income, and the need to sustainably develop the resource base. Field observations showed that the role of the gum and resin sub-sector is

limited to subsistence, therefore extension service aid development of a supply chain that could generate more cash for the poor.

4. During the field survey we observed a lack of information on the amounts of gum and resins that could be produced per area and season. Research must provide such information as a basis for planning production and marketing, and for developing value-added commercialization through involvement of the private sector.

5. As is the case elsewhere in gum and resin producing localities in Ethiopia, we found a lack of gum and resin tapping, processing, storing and transporting technologies and infrastructure. Hence, development of innovative technologies and infrastructure remains a key issue.

6. Informal discussions with local experts and gum and resin producers, showed that access to credit and market information is difficult. This could be remedied by involving the forestry sector in planning for development of the crop and livestock sectors.

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